11 Effects of Resistance Training on Depression and Anxiety

Shawn M. Arent and Brandon L. Alderman

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INTRODUCTION

Worldwide, over 340 million people are impacted by depression.[1] In the United States alone, 16% of the population will experience major depression at some point in their lifetime. In fact, depression is considered a leading cause of disability and is likely to be at least the second leading contributor to worldwide disease burden by 2020.[2] It also appears that depression is linked to increased functional disability and further exacerbates functional disability in individuals suffering from chronic diseases.[3] Likewise, anxiety disorders afflict more than 30 million people in the United States and cost an estimated $42 billion/year. Overall, depression and anxiety are the two most commonly reported mental health disorders.[1,4] To make matters worse, it appears that at least one-third to two-thirds of depressed patients will not experience successful alleviation of symptoms with the first antidepressant therapy prescribed, with as many as 30% being classified as non-responders, that is, not responding to even multiple interventions.[5] Perhaps the more concerning fact is that antidepressants and anxiolytic drugs are both expensive and accompanied by a number of serious side effects. Fortunately, evidence suggests that a viable alternative low-cost alternative therapy, or at least an important adjunct, exists that has positive outcomes and is free from the negative side effects: exercise.

A number of large-scale cross-sectional and prospective-longitudinal studies have demonstrated an inverse association between physical activity and depressive

and anxiety symptoms.[6,7] There has also been an expanding body of meta-analytic evidence supporting moderate to large reductions in both depression and anxiety with exercise[8–11] with effective magnitude often being on par with other traditional psychotherapeutic interventions.[9,11] Although much of the research included in these systematic reviews has primarily used aerobic exercise as the treatment modality, the effects for resistance training (RT) have been shown to be particularly pronounced for depression and both positive and negative moods when included in the analyses.[8,12]

RT has the potential to cause significant increases in muscular strength, hypertrophy, and endurance.[13,14] From a clinical standpoint, it can also impact numerous health conditions such as arthritis, type 2 diabetes, and musculoskeletal dysfunction.[15] It has become increasingly apparent that RT can also significantly and meaningfully enhance psychological states in addition to the well-reported physiological outcomes. Although this psychological effect has received considerably more support for aerobic exercise,[16] the findings for RT have been encouraging. The purpose of this chapter is to provide an overview of the research addressing antidepressant and anxiolytic responses to RT. In addition to summarizing key research findings, considerations related to the conceptualization of intensity, dose–response issues, and potential mechanisms underlying the psychological benefits of RT are addressed where sufficient evidence is available.

RESISTANCE TRAINING AND DEPRESSION

Early work in the area of RT and depression was consistent in finding that this mode of exercise is effective for reducing depressive symptoms.[17–19] Both Doyne et al.[17] and Martinsen et al.[18] found that RT was as efficacious as traditional aerobic exercise such as walking or jogging, with effects persisting for up to 1 year post intervention. Unfortunately, one methodological issue that has sometimes plagued this area of inquiry has been the combination of RT with other exercise modalities, which makes it difficult to discern the unique impact of RT. For example, despite there being positive findings for RT efficacy by Martinsen et al., the RT program used in their study also incorporated coordination and flexibility training. In some cases, the RT protocol was also fairly weak in its design. However, despite these shortcomings, research has largely supported the utility of implementing a RT component to reduce depression.

A recent study[20] compared the antidepressant effects of a 10-week combined moderate-intensity RT and aerobic exercise program to a combined team-sport and cognitive behavioral therapy (CBT) intervention and a control condition in 84 sedentary males. Both the RT/aerobic and team-sport/CBT groups demonstrated reductions in depression scores over the 10 weeks compared to the control condition despite the fact that this was an otherwise healthy population. The magnitude of reduction was somewhat larger in the RT/aerobic exercise group, as was the perception of social support despite the individualized nature of the exercise program. Unfortunately, the researchers provided very little description of the actual exercise protocol and the intensity for both RT and aerobic exercise was established solely based on heart rate.

Beniamini and colleagues[21] examined the feasibility of implementing a 12-week high-intensity (defined as 80% one repetition maximum [1RM]) RT program or a flexibility training program in conjunction with an outpatient cardiac rehabilitation aerobic exercise program in 38 cardiac patients. Compared to the flexibility intervention, the RT group had significantly greater improvements in total mood disturbance, depression/dejection, and fatigue despite only doing three sets of each of four total RT exercises twice a week. Additionally, changes in strength were related to enhanced self-efficacy, mood, and well-being. Perhaps the most important finding, the authors demonstrated that high-intensity RT is a feasible treatment component for cardiac patients.

Unlike the combined RT/aerobic exercise protocols employed by Beniamini et al.[21], McGale et al.[20], and Kohut et al.[22] compared a combined RT and flexibility training program to an aerobic exercise program. Older adults (≥64 years) performed 45 minute workouts three times a week for 10 months. Although the RT component was only performed at moderate intensity and appeared to be fairly low in volume, both groups had similar improvements in depression scores. Given that meta-analytic evidence suggests that yoga and flexibility training have no significant effect on moods in older adults,[12] it is likely that the primary influence on the reductions in depression were due to the RT. Future research needs to make a more concerted effort to separate out these effects while also implementing more carefully prescribed RT protocols, particularly if we hope to establish a causal relationship between RT and reductions in depression.

Resistance Training, Depression, and Obesity

One of the reasons that RT has begun to receive more attention for its potential psychological effects is the burgeoning evidence supporting its physiological benefits. In addition to the obvious effects of progressive RT programs on reduced sarcopenia and increased bone density,[23] it has also been found to lower cortisol responses to acute stress[24]; increase total energy expenditure[25]; and improve hypertension,[26] blood lipids,[27] and glycemic control and glycosylated hemoglobin (HbA1c) levels in individuals with type 2 diabetes.[27] Partly because of these beneficial physiological effects as well as the independent effects for improving body composition by reducing body fat and increasing lean mass, RT has begun to be implemented as part of obesity prevention and treatment programs.[23] This has particular relevance for the topic of exercise and depression as obesity has been shown to increase the risk for depression and depression appears to promote obesity.[28] From an explanatory perspective, the link between obesity and depression may be partially attributed to functional impairments and appearance concerns, two issues that RT is particularly well suited to help ameliorate. For example, a recent study conducted in our laboratory evaluated the effects of RT on physical self-perceptions in Hispanic adolescents.[29] Both male and female students participated in either a 12-week RT program or attended physical education classes as the control group. The RT group demonstrated significant improvements in total physical self-perception, physical condition, body attractiveness, and global self-worth compared to the control group. Moreover, the RT group not only had significant strength gains but also exhibited significant decreases

in percentage of body fat and increases in lean body mass relative to the control group, suggesting a possible connection between increased strength, improved body composition, and improved physical self-perception.

Importantly, given that one of the major side effects of the commonly prescribed antidepressant medications is weight gain, the use of RT as an alternative or adjunct to medication in an already overweight population may be particularly appealing. This is one reason that the traditional approach of managing *either* weight *or* depression without taking into account comorbidities is problematic.[28] Exercise, including RT, may be an appealing and effective solution to this problem. While the existing research comparing exercise to typical pharmacological treatments has been limited to aerobic exercise, the results are encouraging and suggest equivalent short-term improvements but lower relapse rates for exercise.[30,31] Considering the physiological effects of RT, future research comparing this modality of exercise with pharmacological interventions (or in conjunction with pharmacological approaches) is clearly warranted, particularly in situations of comorbid obesity.

Resistance Training, Depression, and Dose Issues

One key component necessary to establish causation in the exercise–mental health relationship is the establishment of a dose–response effect.[16] In addition to epidemiological findings across multiple nations that suggest a dose–response relationship between physical activity and mental health,[6] recent experimental evidence has provided perhaps even more compelling data. Dunn et al.[32] compared two different doses of aerobic exercise (7 kcal/kg/week, which is a low dose [LD], or 17.5 kcal/kg/week, which is a high or public health dose [PHD]) and two different frequencies (3 or 5 days/week) in individuals with mild to moderate depression. An exercise placebo group performed 3 days/week of flexibility training for 15–20 minutes per session. After 12 weeks of training, subjects in the PHD group had significantly greater reductions in depression than those in the LD or placebo groups. Depression scores were reduced by 47% in the PHD group, compared to 30% and 29% in the LD and placebo groups, respectively. The response rate for PHD is at least equivalent to that seen for other depression treatments, such as pharmacological interventions and CBT.[32] Given that no differences were found for exercise frequency (i.e., 3 days vs. 5 days/week), it appears that total energy expenditure was the critical factor for the reduction and remission of depressive symptoms. Notably, the adherence rates in this clinical trial were on par with most pharmaceutical drug trials.[33]

Although these results were observed for aerobic exercise, there is evidence to suggest a potential dose–response effect for RT as well. Carek et al.[34] have suggested that early work in this area[17] supported an "intensity threshold" for treatment efficacy given the similar antidepressant effects of running and RT. As further evidence for a dose–response relationship for RT intensity, Singh et al.[19] conducted a 10 week randomized controlled trial in 32 subjects aged 60–84 years with depression or dysthymia. Subjects were randomized to either a high-intensity (80% 1RM for three sets of eight repetitions for six exercises) supervised progressive RT program three times a week or an attention-control group. RT was found to significantly reduce depression and improve strength in these older adult participants. Further, intensity

of training was a significant independent predictor of the improvement in depression scores. In a follow-up study comparing this dose of exercise to a lower dose, older adults with clinical depression were randomly assigned to 8 weeks of low-intensity (20% 1RM for three sets of eight repetitions per exercise) or high-intensity (80% 1RM for three sets of eight repetitions per exercise) progressive RT or a control condition involving standard care by a general practitioner. High intensity produced significantly greater improvements in clinical depression compared to low intensity or standard care by the general practitioner.[35] There were no significant differences between low intensity and standard care. Over 60% of the high-intensity participants achieved what the authors classified as significant clinical responses (a 50% reduction in therapist-rated depression, compared to 29% of the low-intensity and 21% of the standard care participants). Additionally, 95%–100% compliance was achieved in both RT groups. Strength gains were directly related to the magnitude of reductions in depression, which is notable because these results were achieved using only six total RT exercises per session.

Despite the encouraging findings and potential support for a causal model based on preliminary dose–response effects, it is important to recognize that implementation of such protocols in a real-world setting are not without its challenges in a depressed population. This is particularly true if depression is accompanied by other comorbidities. Individuals with major depression often report feeling a lack of energy to perform basic and essential daily activities. To facilitate implementation and adherence to an RT program, lifestyle interventions are thus likely to be necessary.[28] This could mean incorporating such things as goal setting, self-monitoring, and social support,[36] as well as providing appropriate instruction for RT technique and program design. If appearance concerns are also present, perhaps in conjunction with obesity, it may be difficult to get the individuals to join a gym or fitness facility. In this case, it would be important to design and monitor in-home RT programs. Sparrow et al.[37] successfully implemented a home-based RT program in older adults using a telecommunications system (telephone-linked computer-based long-term interactive fitness trainer). Improvements in strength, balance, and depression were seen with this intervention, suggesting that it may have broader application in this population. It will also be important to adequately educate physicians and psychologists on the benefits of RT as well as proper programmatic design variables to facilitate the most effective delivery of treatment. Special care and programmatic adaptations would need to be taken with depressed individuals who also suffer from functional limitations.

RESISTANCE TRAINING AND ANXIETY

Relative to the literature on exercise and depression, much less research has been conducted to examine the effects of aerobic or resistance exercise on clinical anxiety disorders. However, an extensive body of research supports the anxiolytic benefits of exercise in healthy volunteers[10,36] and exercise also results in significant improvements in various transitory psychological states, including feelings of basic pleasure, moods, and positive affects.[38,39] Indeed, reductions in state anxiety following acute aerobic exercise are one of the most commonly reported psychological benefits within the exercise psychology literature.[10,40–42] State anxiety is characterized by

transient feelings of tension, apprehension, or worry lasting anywhere from moments to hours in duration. Conversely, trait anxiety refers to a more general predisposition to respond across many situations with apprehension, worry, and nervousness. Acute aerobic exercise has been consistently linked with meaningful reductions in state anxiety,[10,16] whereas meta-analytic findings support the beneficial effect of chronic exercise interventions on trait anxiety.[10] These reductions in anxiety following aerobic exercise have been found regardless of how anxiety was operationalized, whether self-report or neurophysiological measures of anxiety were used, and across studies varying widely in methodological rigor. While the anxiolytic effect of exercise has received considerably more support using acute bouts of aerobic exercise, more recent findings for RT have been encouraging.

Many of the earliest studies examining the effects of acute RT on mood and well-being focused on changes in state anxiety. Results from these early studies indicated that acute RT resulted in either little to no change or, in some cases, transient elevations in state anxiety. For instance, Raglin et al.[41] examined anxiety responses to acute bouts of RT and stationary cycling in a sample of intercollegiate athletes. The RT bouts consisted of three sets of 6–10 repetitions at 70%–80% of individual 1RM with a 1–2 minute rest interval between sets for six to seven different strength training exercises. On a separate day, stationary cycling was performed for 30 minutes at 70%–80% of age-predicted maximum heart rate. Their results were interpreted as an increase in anxiety immediately following RT and a significant postexercise reduction in anxiety only emerging at 60 minutes following the stationary cycling condition. However, these two acute bouts of exercise did not represent comparable intensities of exercise and the RT was likely performed at a much higher intensity, thus confounding the findings for mode of exercise with intensity-related effects.

Consistent with these findings, Koltyn et al.[43] found no change in state anxiety following a 50 minute bout of RT performed at self-selected intensity in college students. Garvin et al.[44] similarly found no significant changes in state anxiety following an acute bout of RT performed at 70% of 1RM in college-aged males. These early nonsignificant findings led some researchers to prematurely conclude that acute RT was not associated with anxiolytic benefits.[40] Adding further complexity to the issue, some studies have even found pronounced anxiogenic effects of RT. For example, increases in state anxiety have been observed immediately following acute RT performed with loads > 70% of 1RM.[45,46] A number of studies, however, have observed improvements in state anxiety and other relevant psychological states following acute RT.[45–48] Many of these studies have indicated that factors such as the type of RT routine performed, training load, and intensity may influence the psychological responses accompanying acute RT. These important programmatic variables and subject characteristics might help to explain the mixed findings inherent in the early work in this area of investigation.

Resistance Training and Anxiety: Effects of Training Load

Kraemer and Ratamess[14] stated that "altering the training load can significantly affect the acute metabolic, hormonal, neural, and cardiovascular responses to training." Consistent with this notion, the mixed findings in the literature of acute RT and anxiety could be explained by the use and manipulation of RT intensity. For instance, O'Connor et al.[49] examined changes in state anxiety following bouts of RT performed at 40%, 60%, and 80% of 10 repetition maximum (10RM). They found that RT for 30 minutes at 60% of 10RM (across six exercises), but not 40% or 80% 10RM, resulted in reductions in state anxiety at 90 and 120 minutes following exercise cessation. Focht and Koltyn[48] examined the effects of acute bouts of RT characterized by different loads and rest intervals, with participants completing either 12–20 repetitions/set at 50% of their 1RM incorporating a 45–75 second rest interval between sets or 4–8 repetitions at 80% of 1RM with a 2–2.5 minute rest interval. Significant reductions in state anxiety only emerged following the 50% 1RM condition. However, transient postexercise increases in fatigue were also observed following this dose of exercise. The higher repetition range and shorter rest intervals, which characterized the 50% 1RM condition, may have contributed to the transitory postexercise increase in fatigue. Bibeau et al.[50] conducted a similar study examining resistance exercise of varying intensities and rest intervals. Participants ($N = 104$, $M_{age} = 20.5$ years) from a university weight training class were randomly assigned to one of five treatment conditions in which load (50%–55% 1RM vs. 80%–85% 1RM) and rest intervals (30 vs. 90 seconds) were manipulated. All load/rest combinations resulted in increased state anxiety immediately post exercise, although this was most pronounced in the high-load short-rest condition (i.e., the highest intensity). All conditions resulted in significant reductions in state anxiety at 20 and 40 minutes post exercise. The authors did acknowledge that they might not have adequately implemented a high-intensity RT protocol, which may explain the pattern of anxiety and affective responses. One notable limitation of this study was the use of only four exercises (chest press, seated row, leg press, and hamstring curl), which is inconsistent with current recommendations on proper RT program design.

Focht et al.[51] compared a traditional multiple-set RT condition to a circuit RT condition. The circuit RT condition consisted of performing one set of 10–20 repetitions at 50% of 1RM for 12 different exercises with a 30–45 second interval between exercises, whereas the traditional multiple-set routine consisted of three sets of 6–10 repetitions at 75% of 1RM for four different exercises with 1–2 minutes of rest between sets. The acute session of circuit RT was shown to significantly reduce state anxiety at 120 and 180 minutes post exercise. On the other hand, the traditional multiple-set routine yielded no significant changes in state anxiety, but did result in immediate improvements in body awareness and systolic blood pressure. Ratings of perceived exertion were also found to be significantly higher during the traditional multiple-set routine relative to the circuit training exercise. It should be noted that in several of the aforementioned studies,[46,48,49] some of the postexercise psychological assessments were obtained after individuals were permitted to leave the laboratory setting and resume normal daily activities. Although perhaps increasing external validity, factors other than RT may have contributed to the observed psychological responses and this possibility should be considered when interpreting the findings of such investigations.[16] For instance, Arent et al.[52] found that allowing research subjects to leave the testing environment following the completion of an RT session performed at 50% of the participants' 1RM produced different patterns of affective responses relative to those required to stay in the environment for up to 120 minutes

post exercise, although both groups demonstrated favorable affective responses within 60 minutes post exercise.

Transient increases in state anxiety have been found immediately following 20 minutes of acute RT performed at 75%–85% of 1RM.[45] However, 20 minutes of RT at 40%–50% of 1RM resulted in a significant reduction in state anxiety that was observed within 20 minutes post exercise. Unfortunately, a notable methodological problem in this study limits the interpretability of these findings. The investigators used a time limit to control the RT protocol, likely resulting in a different number of exercises and total sets for each condition. Without adequate control and manipulation of volume, attempting to make conclusions regarding load or intensity (as defined by percentage 1RM) is difficult at best. Based on the extant literature, it is apparent that differences in methodology and inadequate assignment of program design variables have been a hallmark of this area and have limited the ability to make direct comparisons across studies. It is also important to acknowledge that several acute RT studies incorporated programmatic characteristics that likely resulted in participants having to complete at least some sets to the point of momentary muscular failure.[41,44,45,48] This methodological detail could clearly impact how individuals respond to acute RT participation. Overall, current findings suggest that load assignment is an important programmatic factor that influences state anxiety and psychological responses to acute resistance exercise. Moreover, this factor may be even more important if the concept of "momentary failure" is taken into account as an indicator of overall intensity.[47]

Prior investigations in the acute RT and anxiety literature have been characterized by marked differences in load determination and assignment, total volume, repetition ranges, and rest intervals between sets. As Arent et al.[47] have noted, the inconsistency in prescription and lack of control over volume load evident in the literature precludes the ability to draw firm conclusions regarding dose–response effects of acute RT and psychological responses, including anxiety. In an attempt to directly examine the role of intensity while controlling for volume, Arent et al.[47] examined state anxiety and affective responses to acute RT performed at 40%, 70%, and 100% of predetermined 10RM in a sample of 31 college-aged men and women. State anxiety; positive and negative affect; and feelings of energy, calmness, tiredness, and tension were assessed prior to and several times for 60 minutes following each acute RT session. Results revealed that the moderate-intensity bout (70% of 10RM) resulted in the greatest improvements in state anxiety, positive and negative affect, energy, and calmness. These responses emerged immediately following the 70% of 10RM condition and persisted for 1 hour post exercise. Additionally, the high-intensity condition (100% of 10RM) was accompanied by unfavorable psychological responses including transient increases in state anxiety, negative affect, and tension. These findings demonstrate that, when properly defining intensity and controlling for RT volume, acute moderate-intensity RT results in more favorable psychological responses compared to either a low or a high dose of RT (based on intensity). Furthermore, these intensity considerations are consistent with the recent American College of Sports Medicine[53] definitions of RT intensity, which also focus on ratings of perceived exertion. This study represents an ideal dose–response

investigation of psychological responses to acute RT and should be used to guide the design of future research studies aimed at examining the role of intensity in the acute RT–anxiety relationship.

In comparison to the literature on acute resistance exercise and anxiety, very little research has been conducted to date on the potential anxiolytic effects of chronic exercise, particularly in clinically anxious individuals. A recent meta-analytic review of randomized clinical trials examining the efficacy of exercise interventions on anxiety revealed that exercise training resulted in significant reductions in anxiety scores among patients with a chronic illness.[54] Exercise training programs lasting no more than 12 weeks and those with durations of at least 30 minutes resulted in the largest effects. To date, the effects of chronic RT on outcome measures of anxiety have received surprisingly little research. However, several randomized controlled trials have included RT as a modality of exercise in studies of healthy adults,[55] elderly,[56] and among patient populations.[57] These studies have provided preliminary support for RT effects on anxiety symptoms and may help to guide future investigations aimed at clarifying the dose–response and mechanistic effects of the resistance exercise and anxiety relationship.

In one of the few studies conducted to date on chronic exercise and anxiety, Jazaieri et al.[57] conducted a randomized controlled trial of mindfulness-based stress reduction (MBSR) versus aerobic exercise among adults with social anxiety disorder. A standard MBSR program was used comprising 8-weekly 2.5 hour group classes, a 1-day meditation retreat, and daily home practice. For the exercise condition, participants were provided with 2 month gym memberships and were required to complete at least two individual bouts of aerobic exercise at moderate intensity and one group aerobic exercise session per week during the 8-week intervention. Both MBSR and exercise were found to be associated with significant reductions in social anxiety and depression and increases in subjective well-being immediately post intervention and at 3 months post intervention relative to an untreated control group. It is notable that these effects for exercise emerged since intensity of exercise was not monitored and participants received no direct instruction on how to properly use the gym equipment, two factors that could influence psychological outcomes to exercise.

In the previous randomized controlled trials investigating the effects of RT on anxiety, resistance exercise resulted in small but statistically significant reductions in anxiety, although the effect sizes have generally been larger for studies using healthy adult volunteers. Furthermore, similarly to the acute RT and anxiety literature, the improvement in anxiety symptoms has been shown to be best after moderate-intensity RT (defined as 50–60% of 1RM) compared with a higher intensity training (~80% of 1RM).[56,58] The evidence to date supports the conclusion that chronic RT also reduces symptoms of anxiety among healthy adults, although teasing apart the effects of exercise on state versus trait forms of anxiety awaits further investigation. Future research studies need to investigate the effects of RT on patient samples suffering from anxiety, determine which specific forms of anxiety (e.g., generalized anxiety disorder, specific phobias, social anxiety disorder, etc.) benefit most from RT programs, and compare the efficacy of RT as an alternative or adjunct to other established psychotherapeutic interventions for anxiety disorders.

POTENTIAL MECHANISMS

Various biological and psychological mechanisms have been advanced as potential explanations for the antidepressant and anxiolytic effects of exercise. As with issues related to dose–response models, it is imperative that plausible mechanisms be identified to establish causal relationships.[16] Whereas some of the hypotheses or concepts that have been studied to date have shown promise as viable mechanisms, others have not. For example, the notion of exercise primarily serving as a distraction, social support, or placebo has generally been discounted.[16,35] On the other hand, there is potential utility to the self-esteem and mastery effects that exercise may provide,[29] though most of the support for the effects on depression has been correlational in nature. Direct experimental evidence is largely lacking, and well-designed studies should examine this possibility.

Several biological mechanisms have emerged that appear to hold promise in this area. Depression and stress-related disorders have been shown to produce maladaptive structural changes in the hippocampus, amygdala, frontal cortex, and other brain areas that are interconnected and critical to depression and anxiety.[34,59] Neuronal degradation and decreases in hippocampal volume are particularly notable in these stress-related disorders.[60,61] The restoration of these brain regions through plasticity and neurogenesis appears to be one mechanism through which antidepressants exert their effects.[62] A similar effect has been seen with exercise, suggesting that it may share common biological pathways with pharmaceutical interventions.[61] At least part of this response may be due to the upregulation of brain-derived neurotrophic factor (BDNF), which has been shown to support glutamatergic neurons and promote antidepressive and anxiolytic actions.[59] BDNF has been shown to increase with certain antidepressants as well as exercise at specific intensities.[61,63] Other neurotransmitters that have been implicated in mood-altering effects of exercise are serotonin (5-HT) and norepinephrine (NE). Depressed patients typically exhibit decreased secretion of serotonin as well as NE and its precursor, dopamine, in the brain.[64,65] Certain antidepressants (i.e., SSRIs, MAOIs, and tricyclics) function by reregulating serotonin and/or NE levels through reduced degradation or prevention of re-uptake by neurons. Research has found that exercise can result in serotonergic, monoaminergic, and noradrenergic effects similar to those seen with antidepressants.[66]

Exercise has also been associated with an increase in endogenous opioids (most notably β-endorphin and β-lipotropin) and endocannabinoids, both of which have demonstrated analgesic and anxiolytic properties.[67,68] Peripheral β-endorphin has been found to be elevated with long-duration aerobic exercise[69] and high-intensity RT.[70] However, it is uncertain at this time whether or not peripherally derived endorphins exert central effects on the brain because of the impermeability of the blood–brain barrier to these substances. Nonetheless, the possibilities are intriguing, although it is unlikely that either endorphins or endocannabinoids play a solitary role in either antidepressive or anxiolytic responses to exercise.[16] Instead, they may be contributors to the overall neurophysiological response.

Although the aforementioned potential mechanisms have been proposed to explain the psychological benefits of exercise, empirical support for these concepts generally remains sparse, particularly as it pertains to RT. One mechanism that has received

increasing support in recent research, however, is the hypothalamic-pituitary-adrenal (HPA) axis hypothesis. Hypercortisolism due to a dysregulation of the HPA axis is a hallmark of depression[71] as well as anxiety and other stress-related disorders.[72] The end result is often an inappropriate systemic response to stress, which only serves to further exacerbate existing symptomology.[73] It has been established that rectification of control of the HPA axis is instrumental in the alleviation of both depression and anxiety and that failure to do so greatly increases the chance of relapse.[71] In fact, HPA reregulation appears to be how the more effective antidepressants exert their primary effect. Ironically, chronically elevated cortisol has been found to increase the risk of overweight and obesity,[74] which, as noted previously, might serve to exacerbate the effects of depression. Optimal, controlled stimulation of stress response and adaptations of the HPA axis with training are likely means through which exercise produces improvements in anxiety and depression.[16,75] Consistent with this hypothesis, Arent et al.[47] demonstrated that autonomic and HPA axis responses are important mechanisms underlying affective responses to acute RT. Their findings may also explain why anxiogenic responses have been seen with high-intensity RT,[45] due to increases in corticotropin-releasing hormone (CRH) and cortisol. Future research needs to systematically examine the viability of these mechanisms and begin to adequately apply RT as an exercise modality given its clearly promising utility for reducing depression and anxiety.

CONCLUSIONS

After an extensive review of the RT literature related to depression and anxiety, it is clear that much more research is needed. The current body of research generally lacks a progressive coherency that would enable a systematic examination of these topics, with conflicting results likely attributable to the variability in methodologies.[76] The general approach to examining the impact of RT on mental health needs to be more logical. For example, if the effects of training duration are being studied, only the duration of an existing intervention should be varied while holding other variables constant. Changing the intensity, population, load, frequency, and outcome measures along with the duration is not conducive to advancing the knowledge base in this area or establishing causal models. It is worth noting that the complexity of RT prescription far exceeds that of aerobic exercise. There are significantly more variables to consider when structuring an appropriate RT bout or program. These variables include, but are not limited to, repetitions, sets, load, rest intervals, exercise order, eccentric versus concentric emphasis, speed of movement, body part training split, and frequency. It is exactly due to this complexity, though, that there must be a more systematic approach to the examination of the mental health effects of RT.

Despite the limitations of the available literature, there is encouraging evidence for the antidepressive and anxiolytic effects of RT. Regardless of the shortcomings, it is apparent that this modality of exercise is a useful tool for improving both physical and psychological health. Further research in this area and on the unique benefits of RT is clearly warranted. However, there must be a concerted effort to systematically advance the RT studies being conducted in these areas. The approach to this point

has been largely atheoretical and disjointed.[76] It is imperative that we examine the mechanisms underlying the effects of RT on stress-related disorders if we hope to move toward causation. With further work on dose–response and plausible biological mechanisms, we may finally be able to formulate recommendations that can guide public policy.

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